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Goodley

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(54) **STRAP TENSIONING APPARATUS**

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B65B 13/22 (2006.01)

(52) **U.S. Cl.** **100/32**; 100/2; 100/29; 242/419.7

(58) **Field of Classification Search** ..... 100/2, 100/5, 8, 26, 29, 32, 33 PB; 53/399, 582, 53/589; 242/419.7, 417.3
See application file for complete search history.

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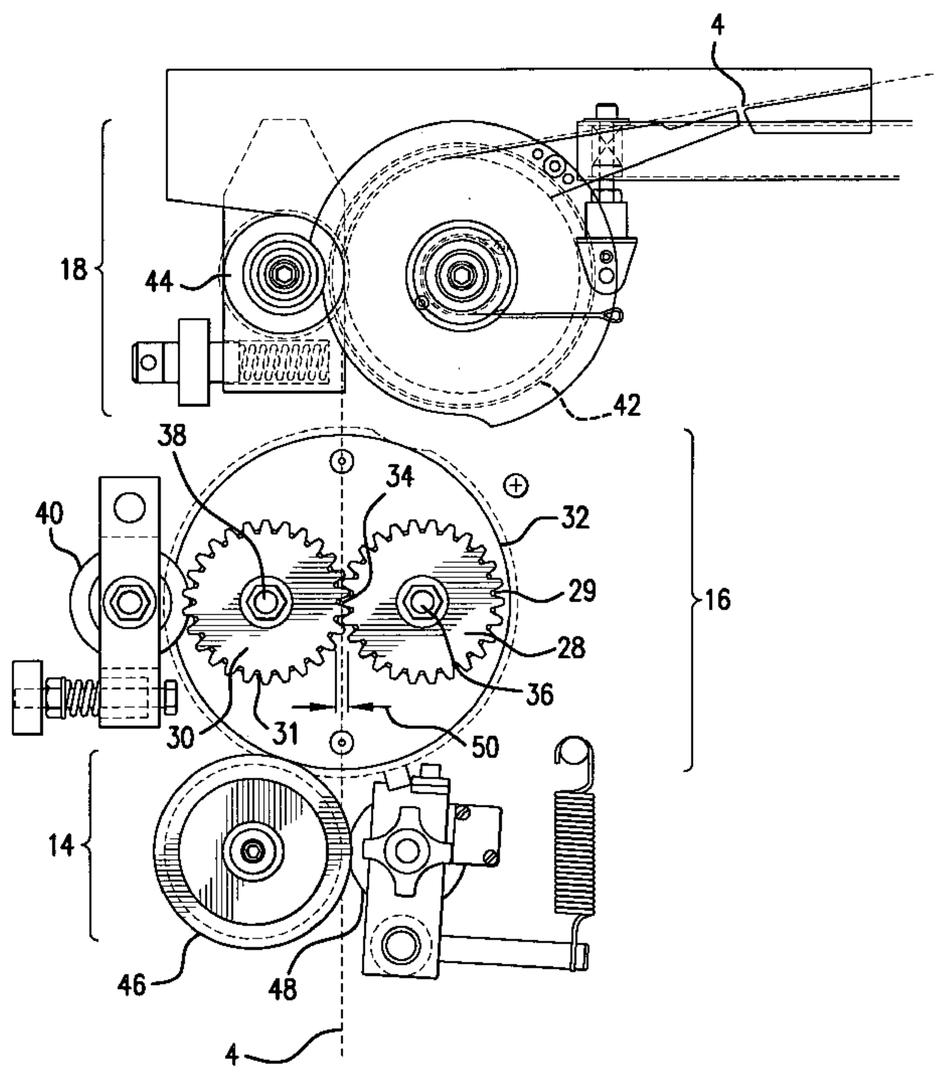
(57) **ABSTRACT**

The present invention is an apparatus for applying high tension to strap in an automatic strapping machine. A rotatable frame has a first and a second position. Two driving wheels are mounted on the frame. In the first position of the rotatable frame, strap passes freely through a gap between the two driving wheels to allow feeding of the strap around an object and take-up of excess strap. In the second position of the rotatable frame the strap frictionally engages the periphery of the two driving wheels. Rotation of the two driving wheels when the rotatable frame is in the second position places high tension on the strap.

23 Claims, 11 Drawing Sheets



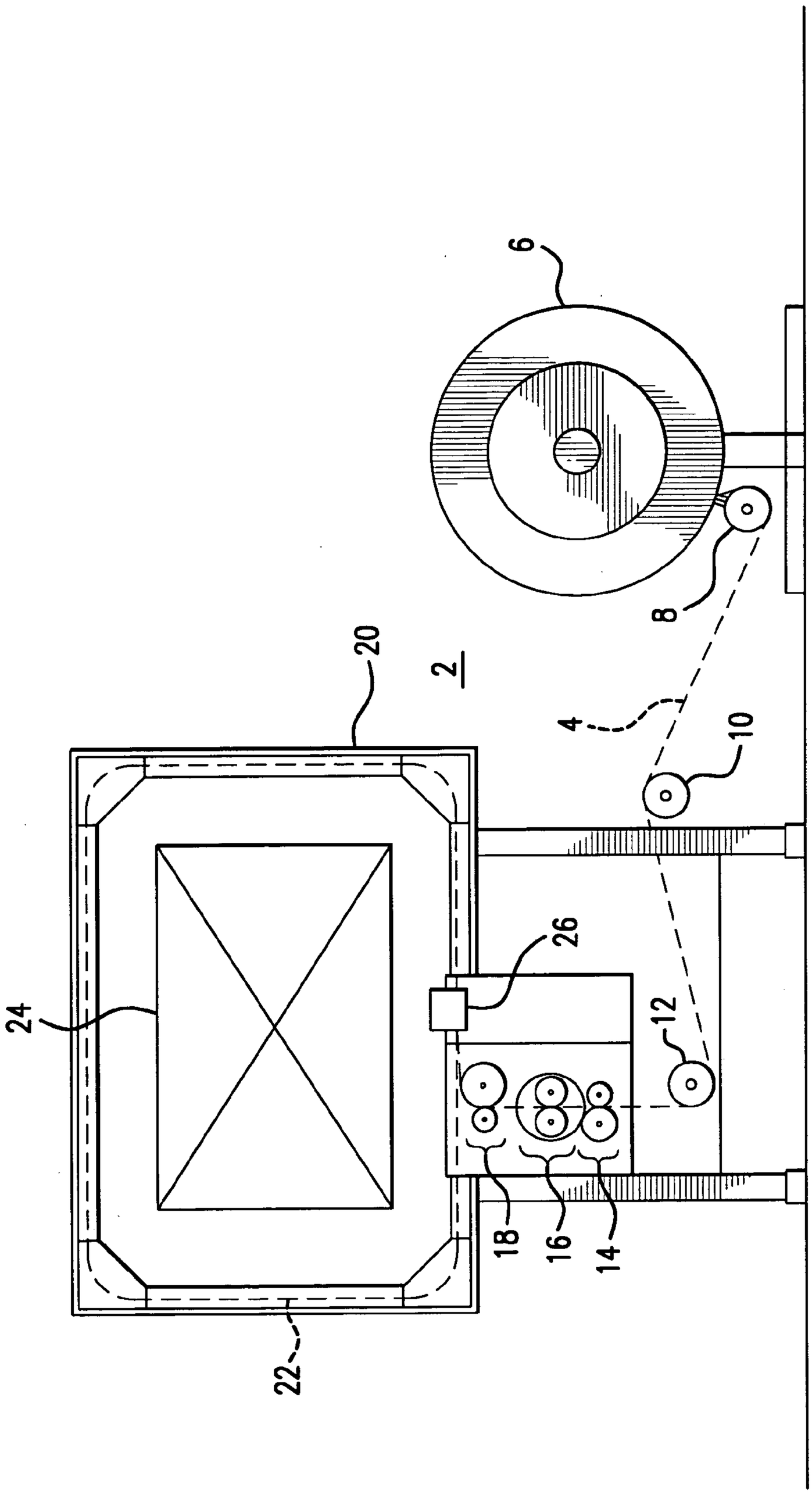


FIG.1

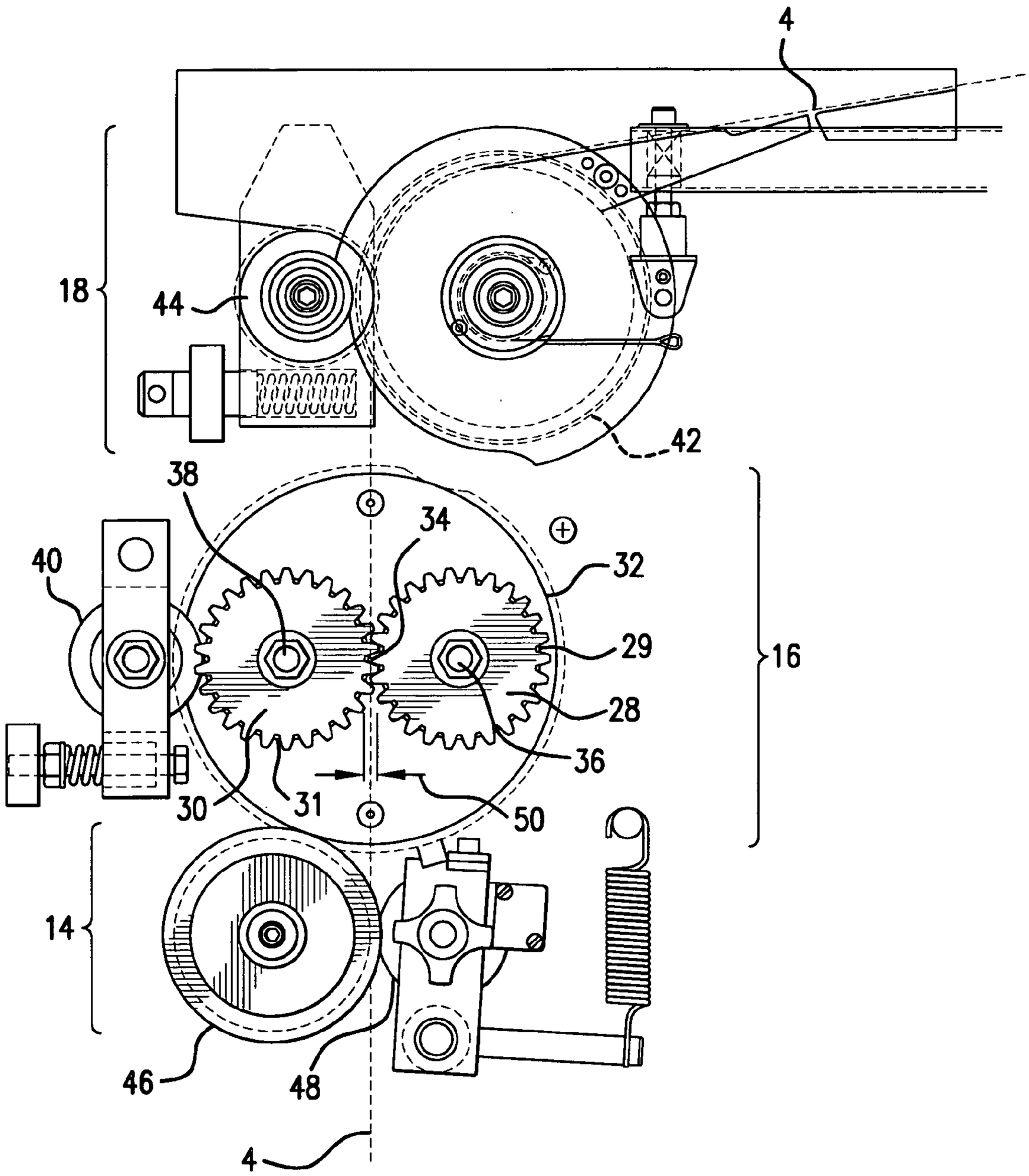


FIG.2

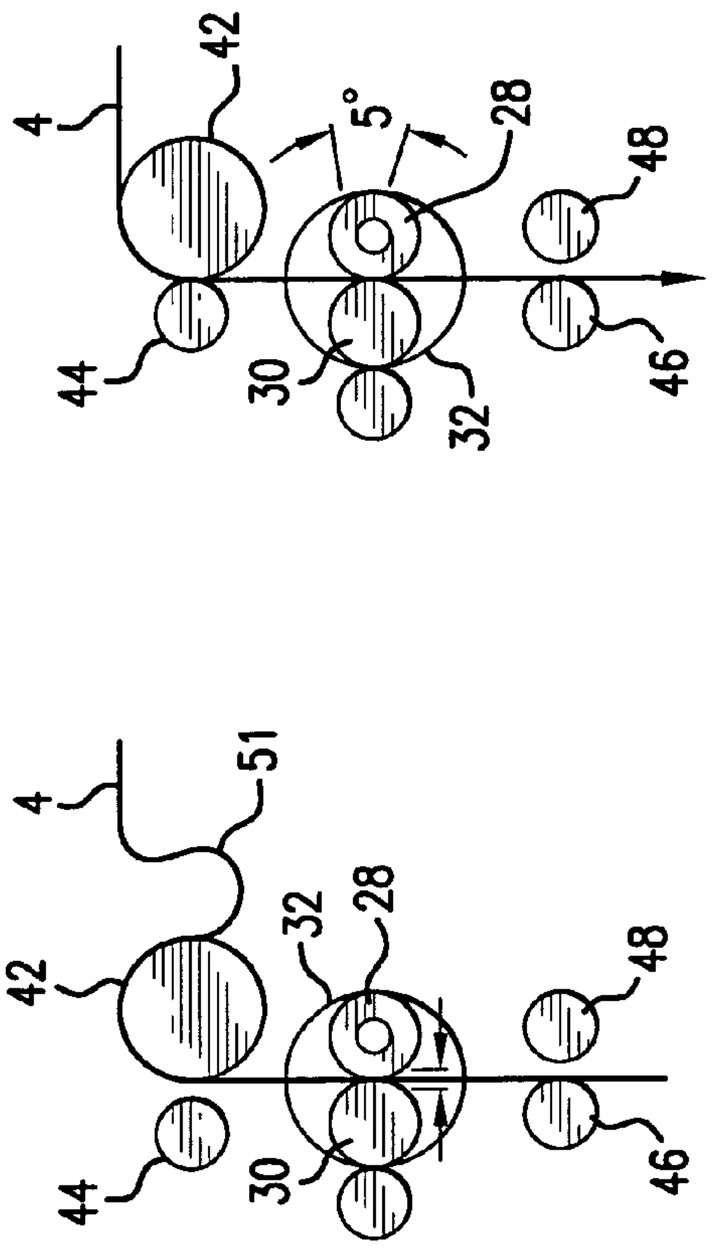


FIG.5

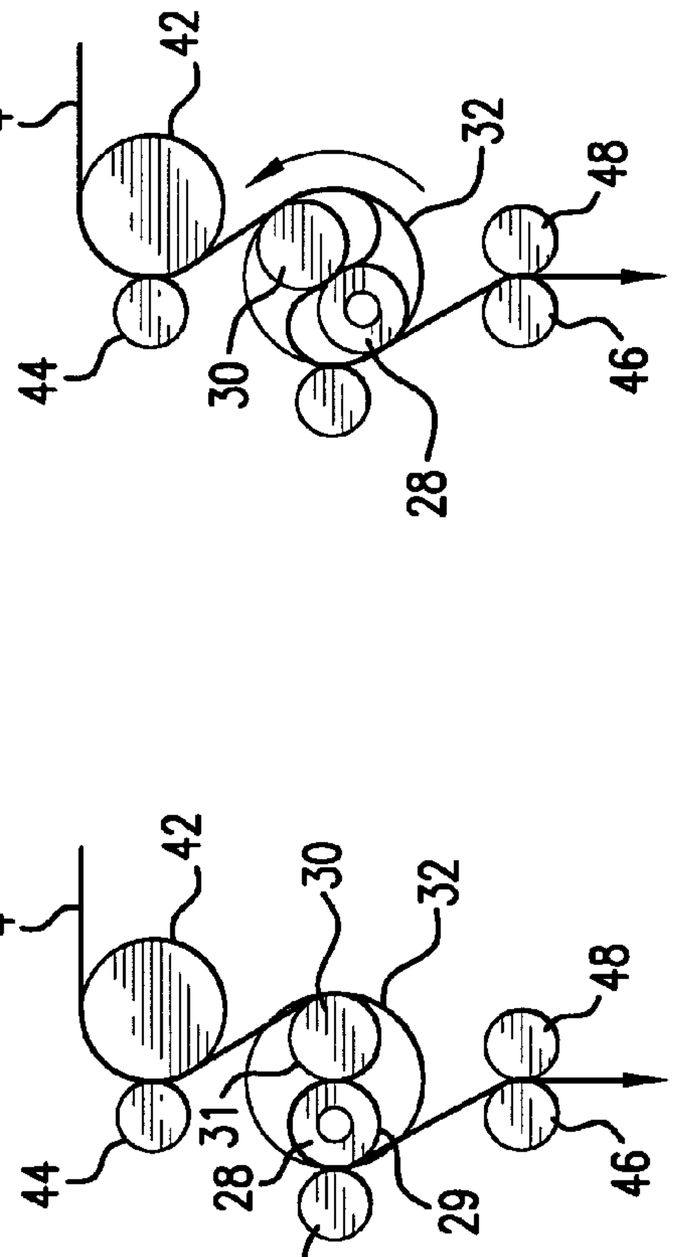


FIG.8

FIG.4

FIG.7

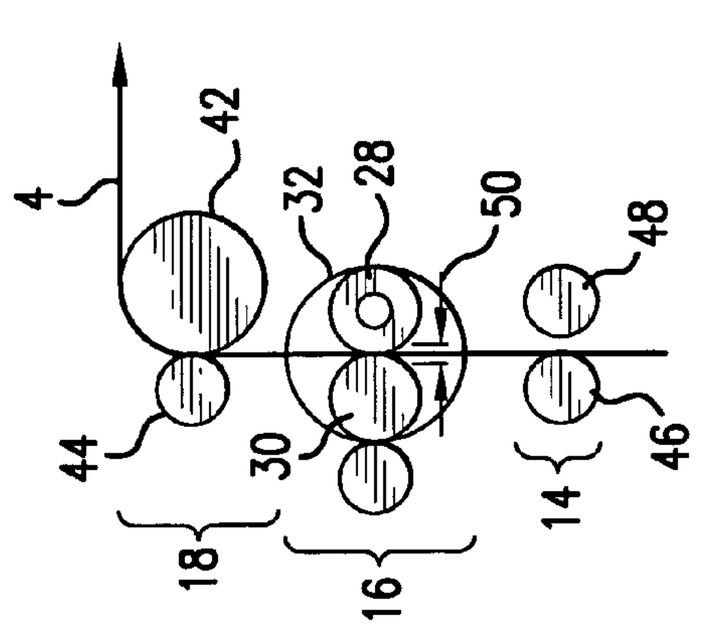


FIG.3

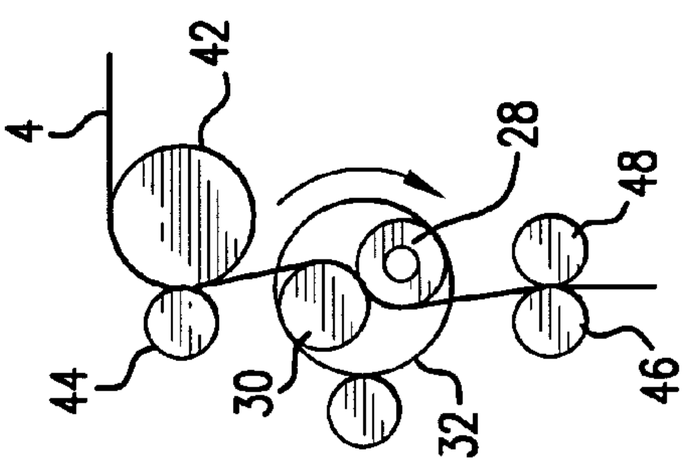


FIG.6

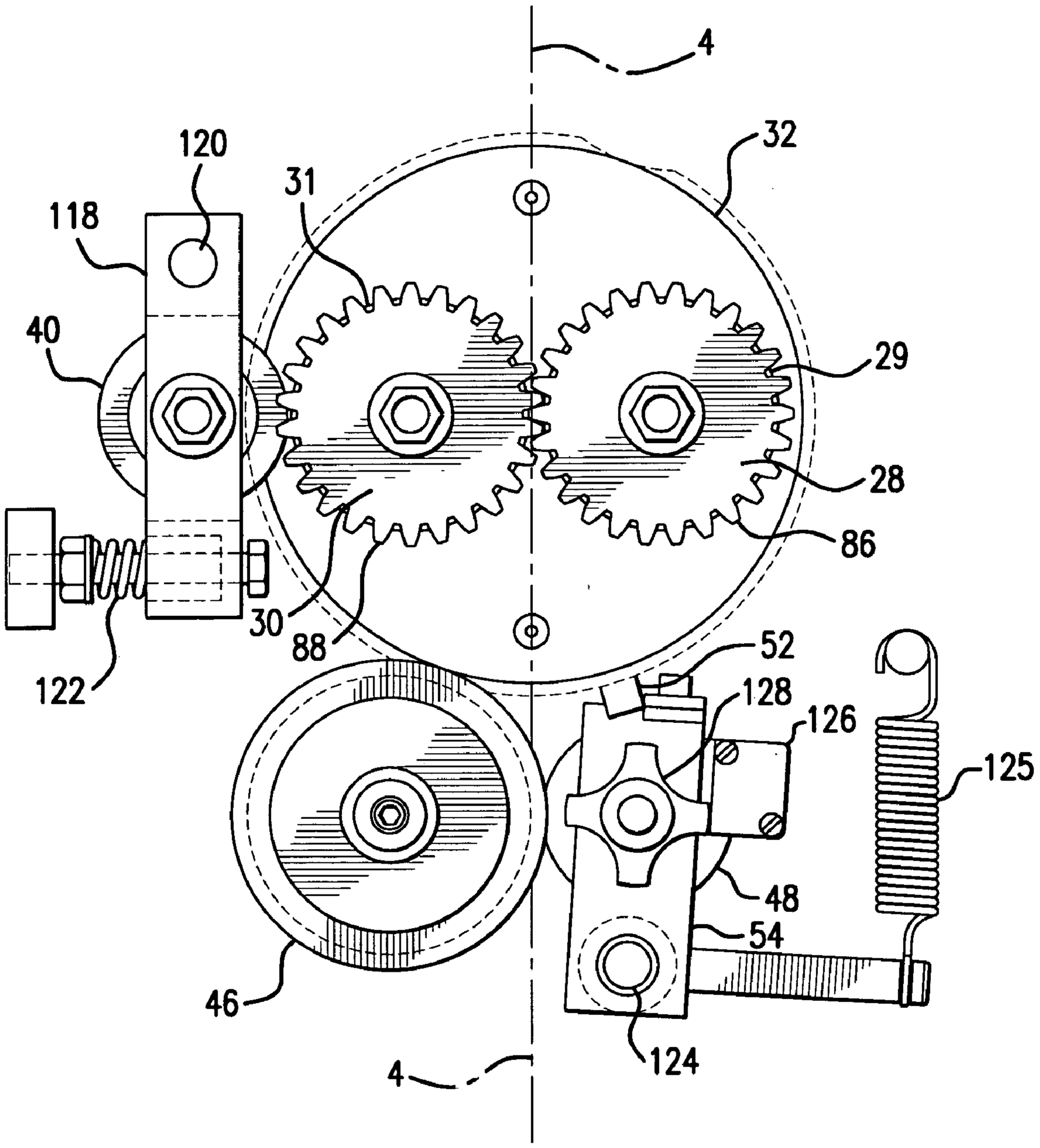


FIG.9

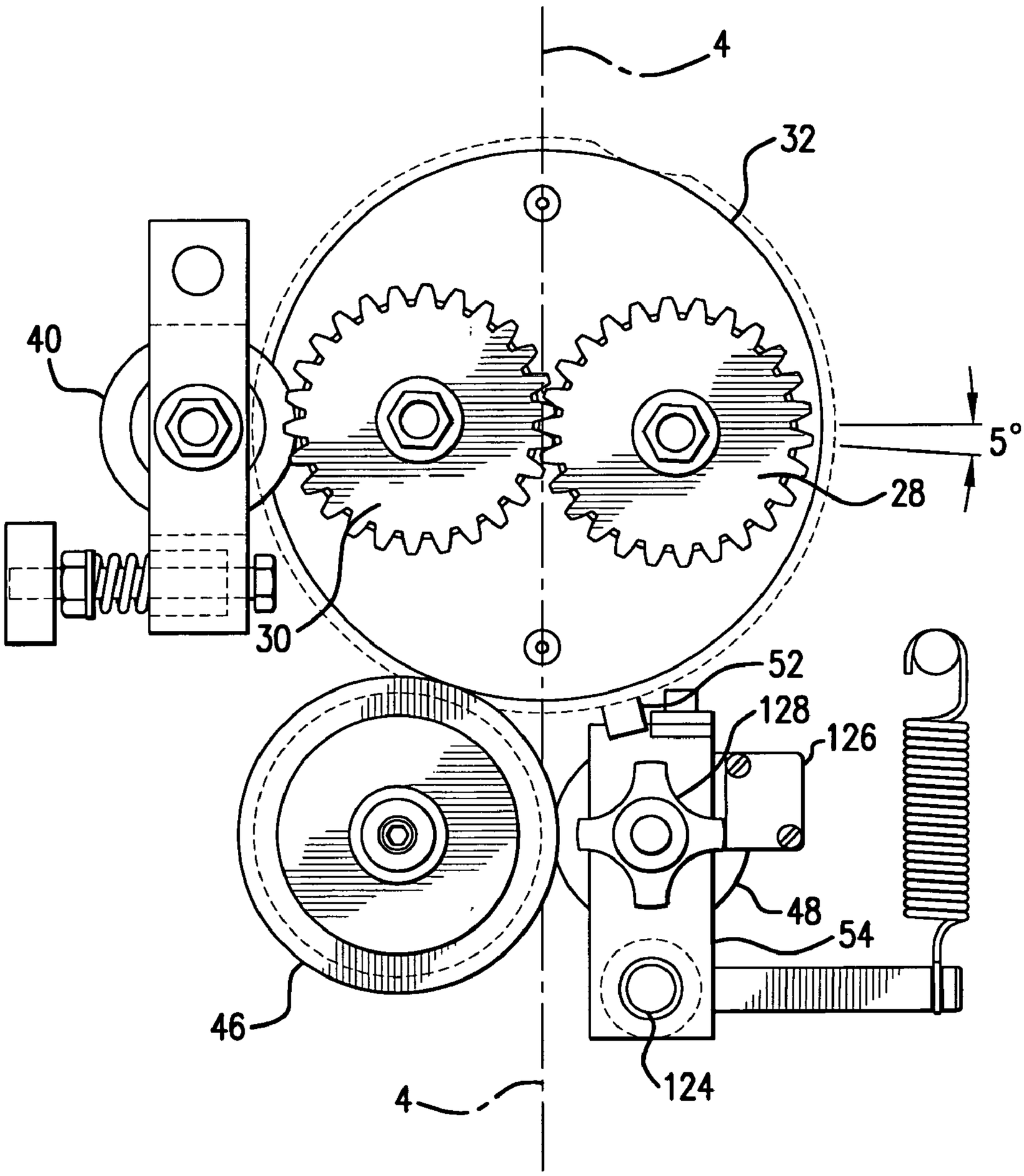


FIG.10

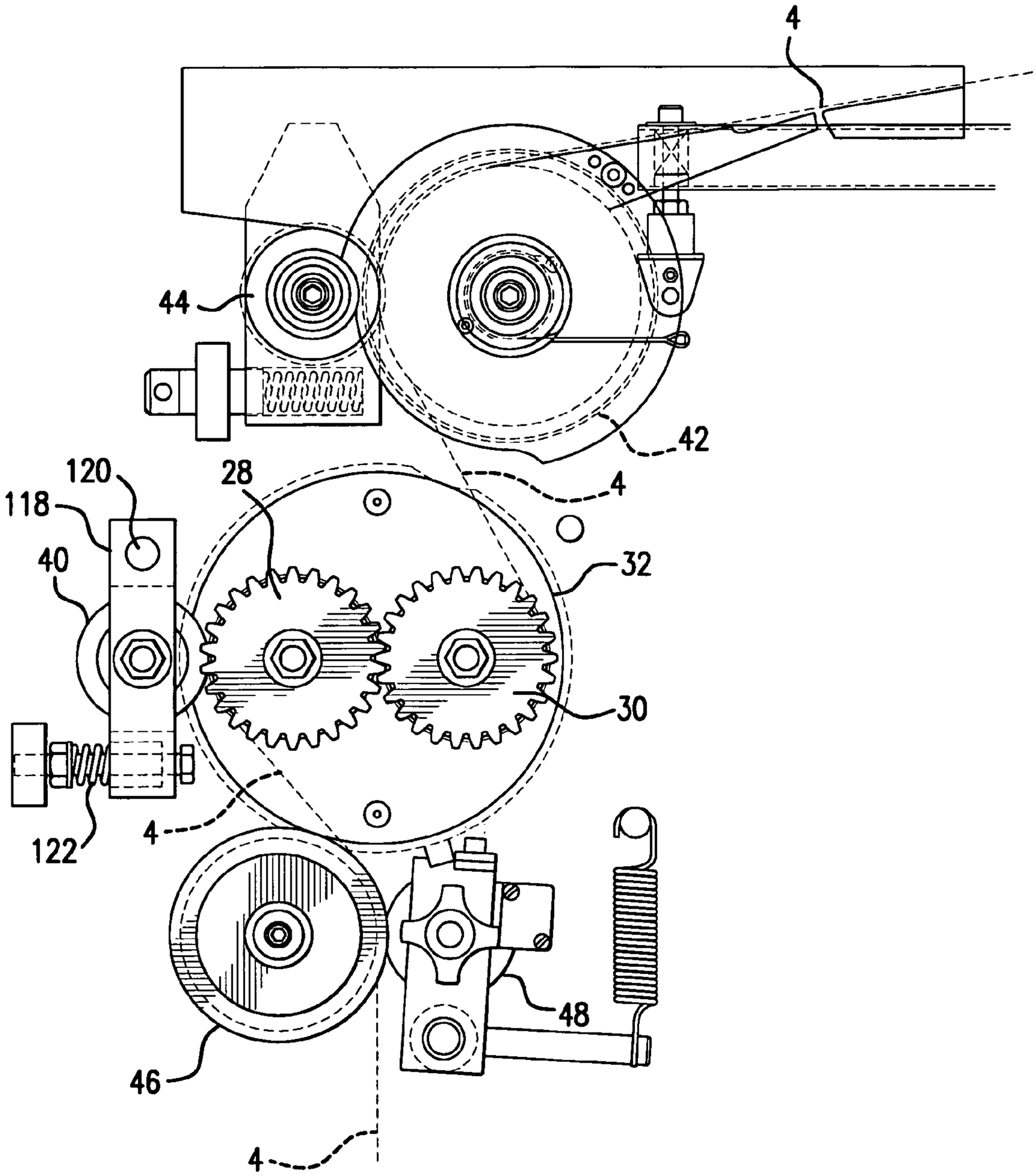


FIG.11

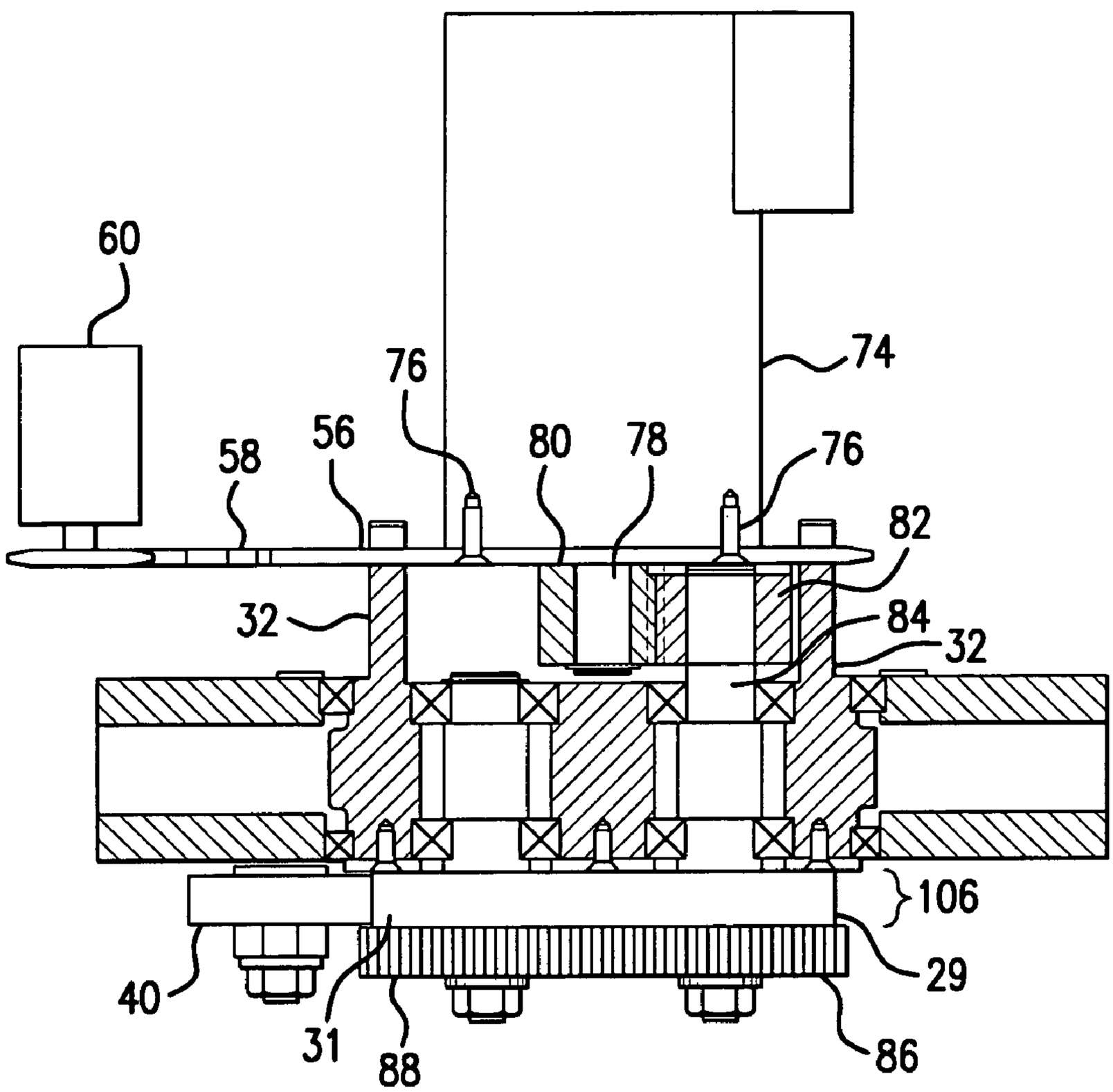


FIG.12

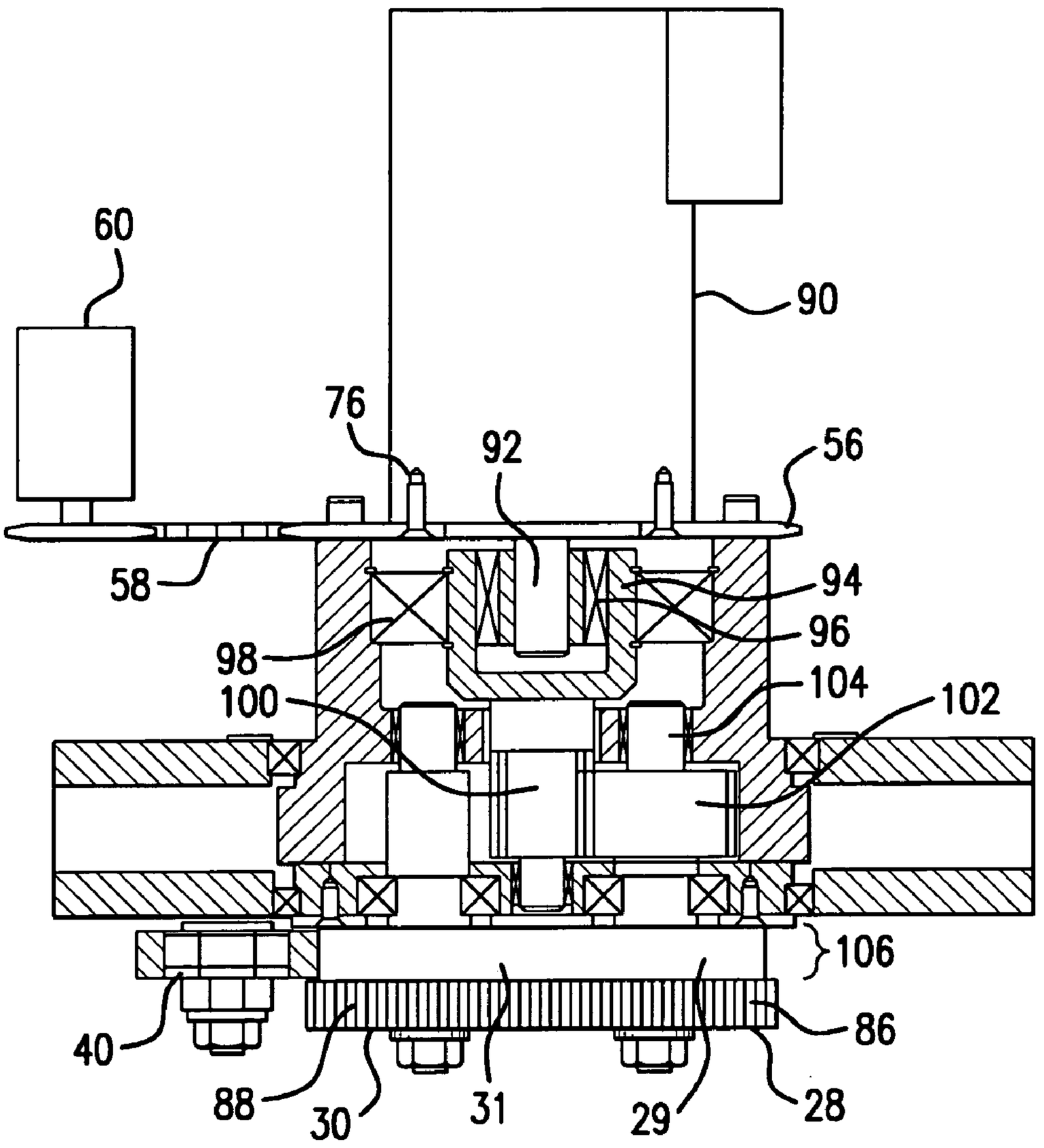


FIG.13

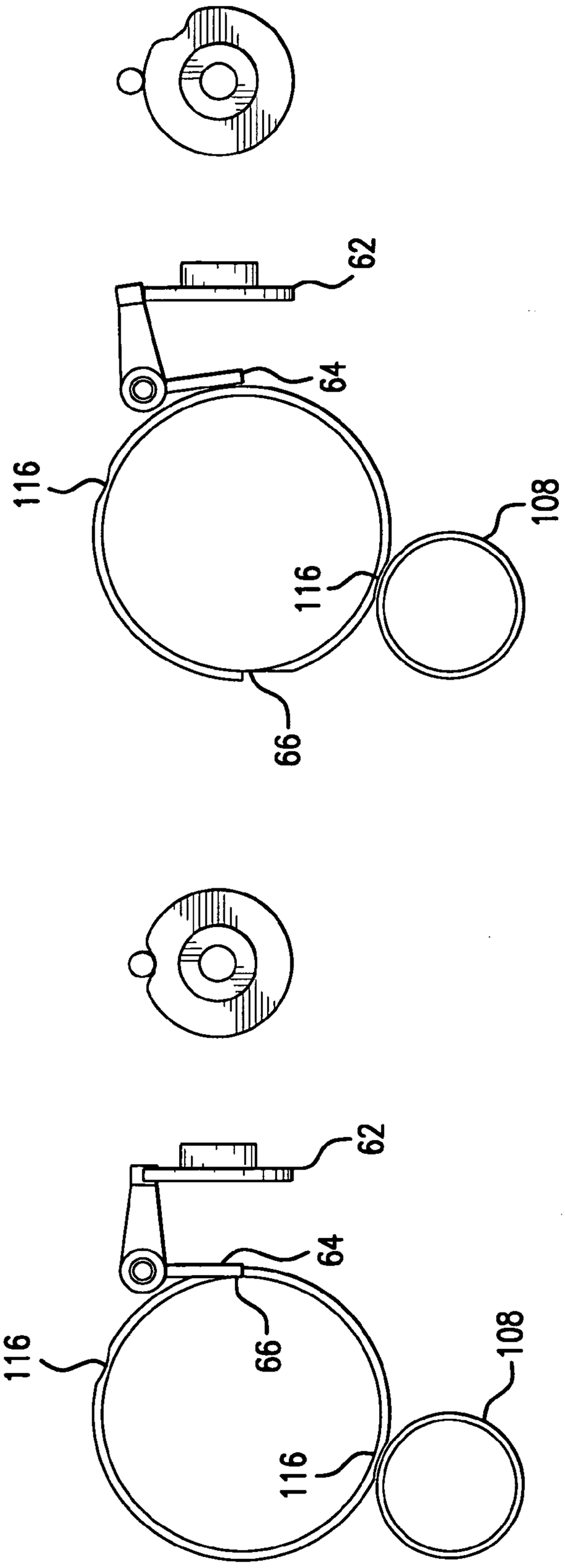


FIG. 14

FIG. 15

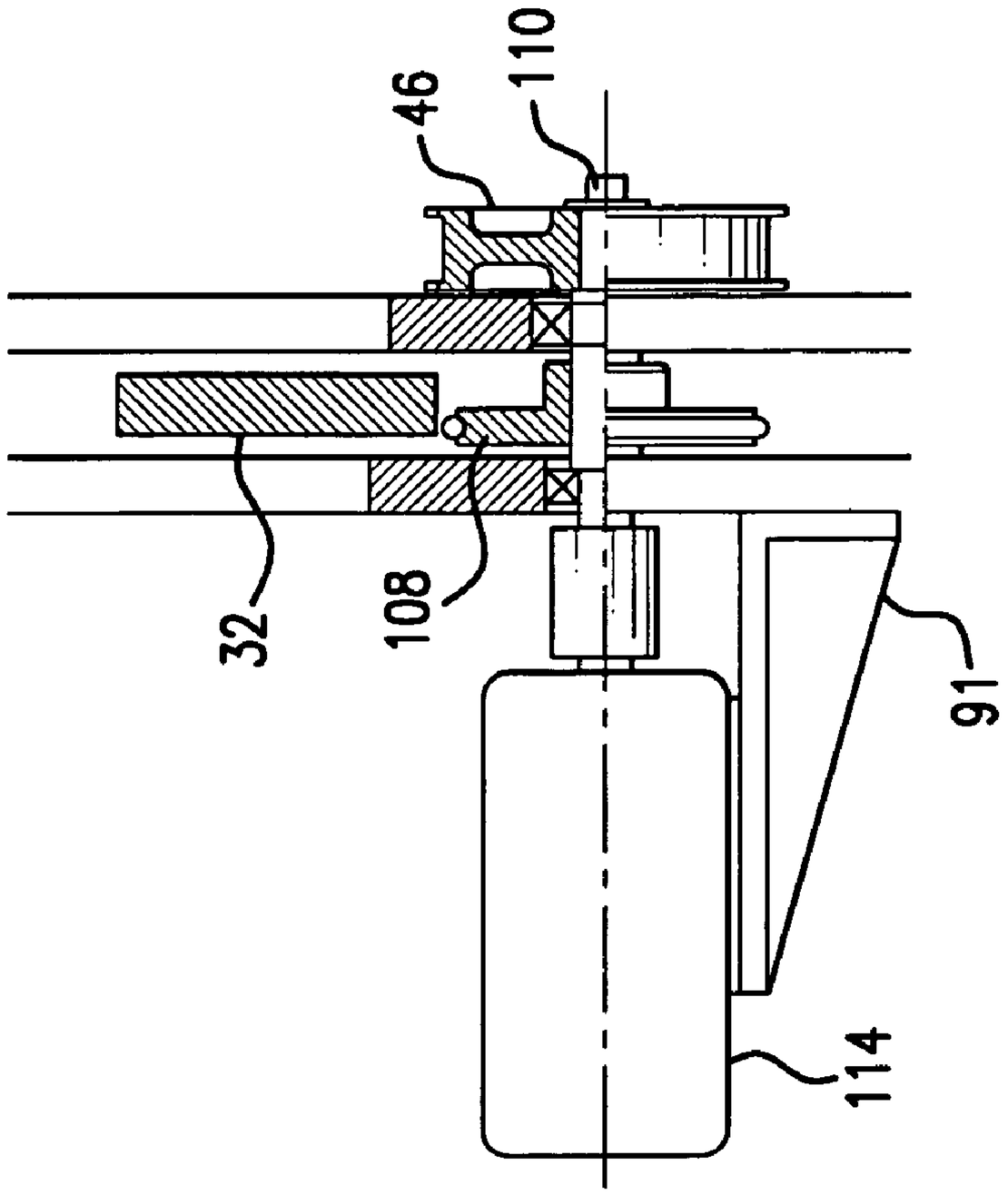


FIG. 17

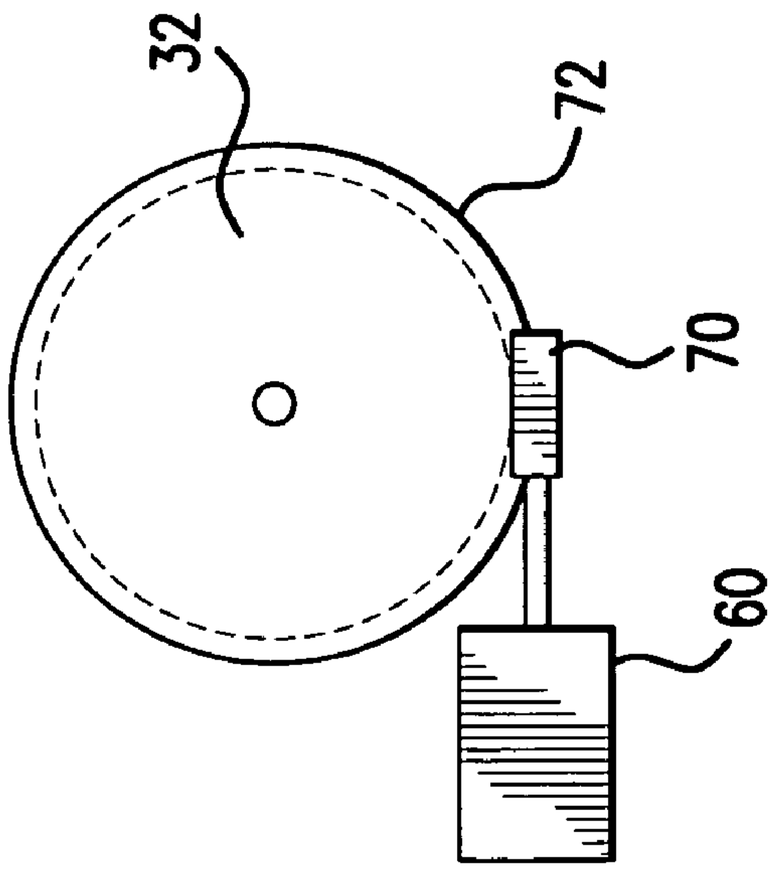


FIG. 16

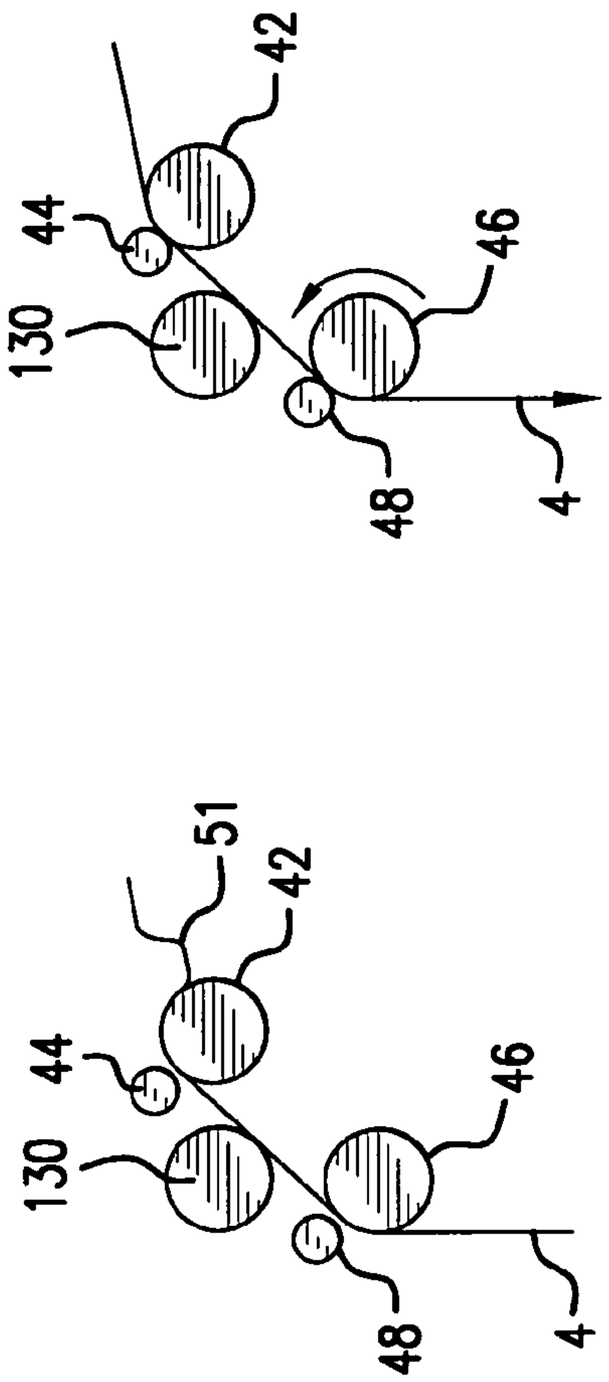


FIG.20

FIG.19

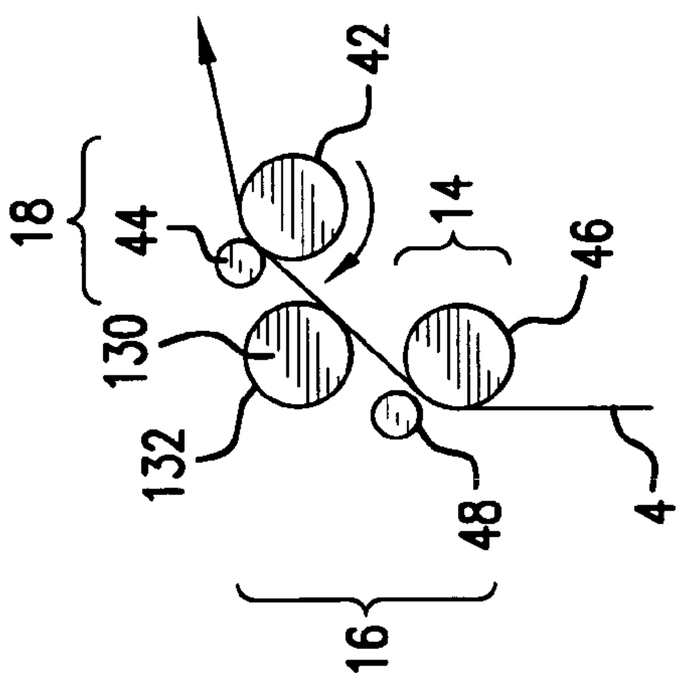


FIG.18

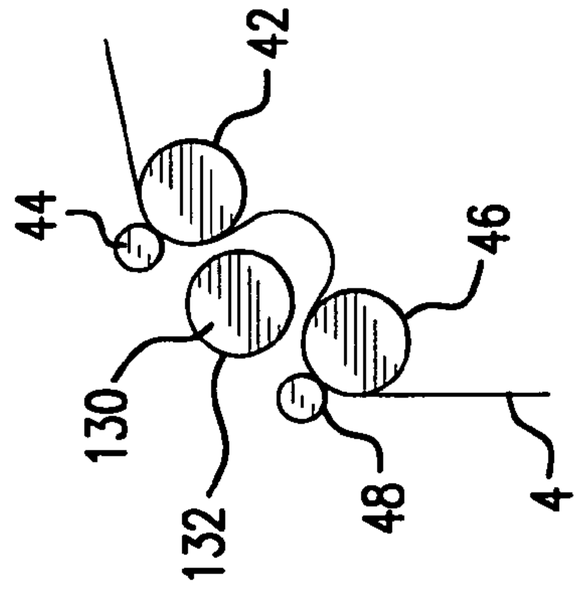


FIG.23

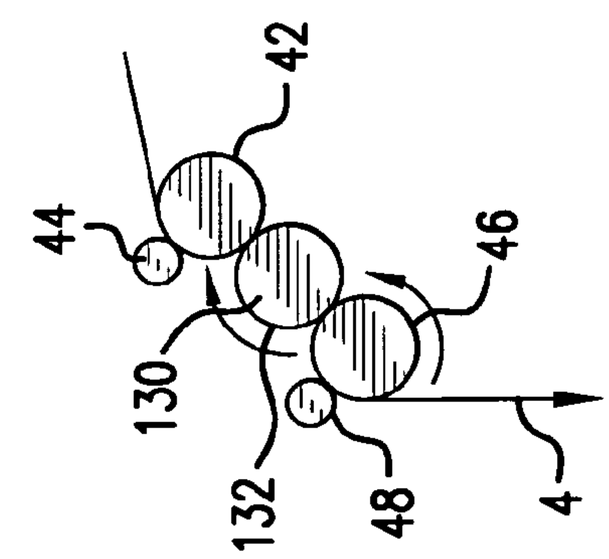


FIG.22

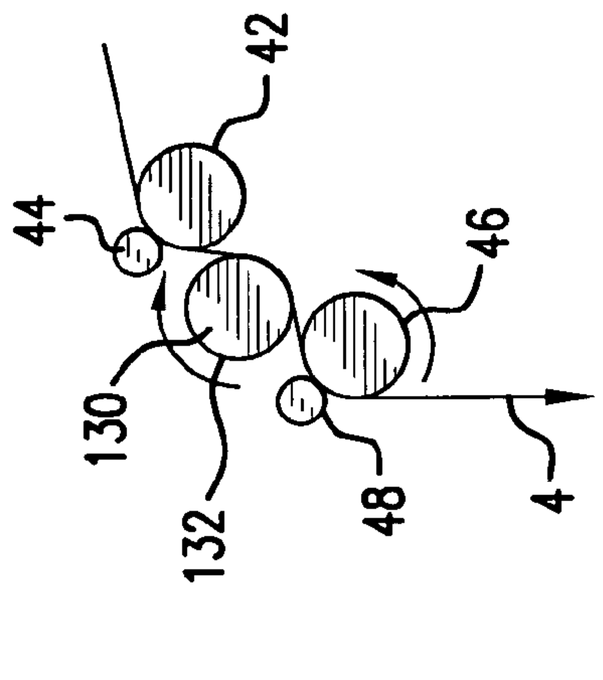


FIG.21

STRAP TENSIONING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present Invention is an apparatus for tensioning a strap in a strapping machine, such as a high-speed automatic strapping machine. The tensioning apparatus is used to draw a high tension on the strap to securely hold the strap around an object. The present Invention also is a strapping machine incorporating the disclosed tensioning apparatus.

2. Description of the Related Art

Automatic strapping machines are known in the art for placing plastic strap around a package or other object(s) to be strapped for the purpose of reinforcing the package or binding several objects together. In operation, an automatic strapping machine feeds plastic strapping material at high speed around an object to be strapped to form a loop of strap. The strapping machine then secures a first end of the loop of strap and takes up excess strap. The strapping machine places a high tension on the strap, cuts the strap, and secures the strap by welding or other conventional means, completing the strapping of the object and creating a new first end of the strapping material, ready to strap a new object.

The operations performed by a modern strapping machine occur very quickly. A modern strapping machine may feed strap at a speed of fifteen feet per second or higher around the object to be strapped. The strap generally travels through the strapping machine and around the object to be strapped through guides. The steps of securing the first end of the strap, tensioning of the strap, cutting the strap and welding the tensioned loop of strap likewise occur very quickly.

SUMMARY OF THE INVENTION

The mechanism of the present Invention takes up excess strap and properly tensions the strap in an automatic strapping machine in preparation for cutting and welding the strap. The present Invention moves the strap between two different strap paths through the tensioning apparatus: a first, or feed/take-up strap path and a second, or tensioning strap path. In the first strap path, strap may be fed or taken up in a relatively straight line through the tensioning apparatus with no or minimal contact between the strap and the tensioning apparatus.

In the second strap path, the strap is elastically bent around a strap-engaging surface of a strap-engaging member, partially wrapping the strap around the strap engaging member. The strap-engaging member may comprise a belt, wheel or any other object that may frictionally engage a strap. The tensioning apparatus may include one or more strap-engaging members. An initial tension is applied to the strap. The initial tension applied to the strap causes the strap to apply force to the strap-engaging surface of the strap-engaging member because of the partial wrap of the strap around the strap-engaging member. The force applied by the strap to the strap-engaging surface creates frictional engagement between the strap-engaging surface and the strap. The frictional engagement between the strap-engaging surface and the strap allows the strap-engaging member to apply tension to the strap. The tension applied to the strap by the strap-engaging member causes the strap to exert more force against the strap-engaging member, increasing the frictional engagement between the strap and the strap-engaging member and allowing the strap-engaging member to apply additional tension to the strap until a predetermined high tension is achieved. At the conclusion of the tensioning process, the present invention moves the strap from the second, or tensioning strap path to the first, or feed/take-up strap path, readying the strapping machine to feed strap around a new object to be strapped.

The first embodiment of the tensioning apparatus of the present Invention comprises two wheels (hereinafter referred to as the first and second driving wheels) rotatably attached to a rotatable frame. The rotatable frame has a first and a second position. When the rotatable frame is in the first position, the strap may pass freely through a gap between the first and second driving wheels to allow the feed of strap around the object and to allow take-up of excess strap.

When tension is to be applied to the strap, the rotatable frame rotates to the second position. The rotation of the rotatable frame to the second position causes the strap-engaging surfaces of the first and second driving wheels to touch the strap, but not to operably engage the strap. An initial tension is placed on the strap by engagement of the first driving wheel and a driving wheel nip followed by rotation of the first driving wheel. For purposes of this application, a 'nip' is an object that presses the strap against a wheel for the purpose of applying force to the strap and wheel so that the wheel may frictionally engage the strap. Alternatively, the initial tension may be placed on the strap by the take-up assembly or by the take-up assembly in cooperation with a driving wheel nip. The initial tension applied to the strap causes the strap to exert force against, and to frictionally engage, the strap-engaging surfaces of the first and second driving wheels. The first and second driving wheels then are rotated and the frictional engagement between the strap and the surfaces of the first and second driving wheels pulls the strap and places the strap under high tension.

A friction drive mechanism may be used to accommodate the change in length of the strap path caused by movement between the first and second strap paths. The feeding of the strap to form the loop around the object to be strapped, the securing of the free end of the strap, and cutting and welding of the strap all may be performed by conventional means.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a strapping machine.

FIG. **2** is a diagram showing the relationship of the tensioning mechanism of the present Invention to the take-up and feed mechanisms in a strapping machine.

FIG. **3** is a schematic diagram showing the strap tensioning mechanism of the present Invention in a first position during feeding of strap.

FIG. **4** is a schematic diagram showing the present Invention at the completion of feeding.

FIG. **5** is a schematic showing fast take-up of excess strap from the object to be strapped.

FIG. **6** is a schematic showing the start of rotation of the rotatable frame.

FIG. **7** is a schematic showing the strap tensioning mechanism in the second position and the placing of high tension on the strap.

FIG. **8** is a schematic showing return of the rotatable frame to the first position.

FIG. **9** is a plan view of the tensioning and take-up mechanisms in the feed position.

FIG. **10** is a plan view of the tensioning and take-up mechanisms in the take-up position.

FIG. **11** is a plan view of the feed, tensioning and take-up mechanisms in the tensioning position.

FIG. **12** is a sectional view of a first embodiment of the driving wheel drive mechanism.

FIG. **13** is a sectional view of a second embodiment of the driving wheel drive mechanism.

FIG. **14** is schematic of a friction drive and rotatable frame locking mechanism with the rotatable frame in the feed position.

FIG. **15** is a schematic of a friction drive and rotatable frame locking mechanism with the tensioning mechanism in the tensioning position.

FIG. **16** is a schematic of a worm gear drive for the rotatable frame.

FIG. **17** is a cutaway view of a portion of a friction drive mechanism.

FIG. **18** shows a second embodiment in the feed position.

FIG. **19** shows the second embodiment at the completion of feeding.

FIG. **20** shows the second embodiment during fast take-up.

FIG. **21** shows the second embodiment during the transition to final tension.

FIG. **22** shows the second embodiment during application of tension.

FIG. **23** shows the second embodiment during the return to the feed position.

DESCRIPTION OF AN EMBODIMENT

FIGS. **1**–**17** show a first embodiment of the Invention. As shown by FIG. **1**, a strapping machine **2** pulls strap **4** (indicated by dashed line) from strapping roll **6** past idler rollers **8**, **10** and **12**. The strap **4** is pulled past disengaged take-up assembly **14** and disengaged tensioning assembly **16** by feed assembly **18**. Strap **4** is fed through guides **20** so that a loop **22** of strap **4** is formed around the object to be strapped **24**. The free end of the strap **4** is secured by conventional securing means by securing-cutting-welding assembly **26**. Completion of loop **22** causes feed assembly **18** to disengage strap **4**. Take-up assembly **14** engages strap **4** and takes up excess strap **4**. Take-up assembly **14** then disengages and the tensioning assembly **16** engages and applies high tension to the strap **4** around the object to be strapped **24**. The strap **4** is cut and welded by securing-cutting-welding assembly **26**, finishing the operation.

The present Invention addresses specifically tensioning assembly **16** for applying a high tension to the strap **4**. The present Invention also addresses means for taking up excess strap **4**. Means for feeding strap **4** around an object to be strapped **24** are well known in the art, as are means for securing the free end of the strap **4**, means for cutting the strap **4** and means for welding the strap **4**.

FIG. **2** shows the physical relationship of the tensioning assembly **16** of the first embodiment to feed assembly **18** and take-up assembly **14**. Strap **4** is indicated by a dashed line in FIG. **2**. In the present Invention, either of two strap paths through the tensioning apparatus may be selected: a feeding/take-up strap path (also referred to herein as a first strap path), and a tensioning strap path (also referred to herein as a second strap path). FIG. **2** shows strap **4** in the first, or feed/take-up strap path.

From FIG. **2**, tensioning assembly **16** has a first driving wheel **28** having a strap-engaging surface **29** and a second driving wheel **30** having a strap-engaging surface **31** mounted on a rotatable frame **32**. Rotatable frame **32** is rotatable through approximately 180 degrees. The axis of rotation **34** of the rotatable frame **32** is located approximately half way between the centers of rotation **36**, **38** of the driving wheels **28**, **30**. The driving wheels **28**, **30** are equipped with a driving wheel 'nip' **40**.

Certain other parts of the strapping machine are shown by FIG. **2**. Those parts include the feed assembly **18** comprising a feed wheel **42** and its corresponding feed nip **44**. Take-up assembly **14** is shown on FIG. **2** and comprises a take-up wheel **46** and a take-up nip **48**. All wheels **28**, **30**, **40**, **42**, **44**, **46**, **48** are slightly wider than the strap **4**. For example, for a one-half inch wide strap **4**, the wheels **28**, **30**, **40**, **42**, **44**, **46**, **48** would be about five-eighths of an inch wide.

The sequential operation of the tensioning assembly **16** of the present Invention in a strapping machine **2** is described below making reference to FIGS. **3** through **8**.

Strap Feed: FIG. **3** illustrates the feed of strap **4** through the strapping machine **2**. FIG. **9** shows more detail of the tensioning assembly **16** and the take-up assembly **14** during strap **4** feed. The position of the rotatable frame **32** as illustrated in FIG. **3** is referred in this application as the "first position," causing the strap **4** to follow the first, or feed/take-up strap path. Strap **4** (shown by the heavy line in FIG. **3**) is fed by feed wheel **42** and feed nip **44**. The feed nip **44** presses against the strap **4** and feed wheel **42**. In FIG. **3**, the feed wheel **42**, the feed nip **44**, or both are driven. In the feed position, take-up nip **48** is separated from strap **4** and thus take-up wheel **46** does not engage strap **4** and exerts no force on strap **4**. The driving wheels **28**, **30** are oriented so that the strap **4** passes through a gap **50** between the wheels **28**, **30**. The driving wheels **28**, **30** impart no force on the strap **4**.

During the feeding of strap **4**, the feed wheel **42** is driven at a high rate of speed. The frictional engagement between the feed wheel **42** and the strap **4** propels the strap **4** at a high rate of speed through guides **20** (FIG. **1**) around the object to be strapped **24**, forming loop **22**.

Feed Complete: FIG. **4** illustrates the strapping machine **2** after adequate strap **4** has been fed to complete loop **22**. Mechanical or electrical sensors may detect the end of the strap **4** or a buckle **51** in the strap **4** or both, indicating that additional strap **4** is not required.

When the loop **22** is complete as detected by the sensors, the feeding of the strap **4** by the feed wheel **42** stops, either by interrupting the rotational motion of the feed wheel **42** or by disengaging the feed nip **44** from the feed wheel **42**, thereby reducing the frictional engagement between the feed wheel **42** and the strap **4**. In the embodiment illustrated by FIG. **4**, the feed nip **44** separates from the feed wheel **42** so that none of the wheels **28**, **30**, **40**, **42**, **44**, **46**, **48** exerts force on the strap **4**.

The free end of the strap **4** is then secured by conventional means in securing-cutting-welding assembly **26** (FIG. **1**). Conventional means for securing the free end of the strap **4** include use of grippers that receive and hold the free end of the strap **4** and do not release the free end in response to tension applied to the strap **4**.

Fast take-up: FIG. **5** illustrates one embodiment for the take-up of excess strap **4**. FIG. **10** provides more detail of the take-up assembly **14** and tensioning assembly **16** when strap **4** is being taken up. Take-up of excess strap **4** may be performed by take-up wheel **46** and take-up nip **48**. The rotatable frame **32** rotates approximately five degrees clockwise.

The movement of the rotatable frame **32** does not materially change the relationship between the driving wheels **28**, **30** and the strap **4**. The strap **4** still follows the first, or feed/take-up strap path and strap **4** still may pass freely through the gap **50** (FIG. **2**) and the driving wheels **28**, **30** impart no force on strap **4**. The rotatable frame **32** is operably connected to the take-up wheel **46** or take-up nip

48 so that motion of the rotatable frame **32** by approximately five degrees as illustrated by FIG. **5** causes one or both of take-up wheel **46** and take-up nip **48** to move until take-up wheel **46** and take-up nip **48** engage the strap **4**. The take-up wheel **46** then is powered and pulls the excess strap **4** in the direction of the arrow indicated by FIG. **5**. Optionally, feed nip **44** may move toward feed wheel **42**, thereby engaging the strap **4** and guiding strap **4**. Feed nip **44** and feed wheel **42** are not powered and are free-wheeling and thus impart no pulling force on the strap **4**. When sufficient excess strap is removed, the power to the take up wheel **46** is cut, stopping the rotation of take up wheel **46**.

One mechanism for separating take-up wheel **46** and take-up nip **48** and thereby interrupting frictional engagement between the take-up wheel **46** and the strap **4** is a projection **52** (FIGS. **9**, **10**) on the rotatable frame **32** to engage and disengage the take-up nip frame **54**. When the rotatable frame **32** is in the first, or feed, position, the projection **52** may restrain the motion of the take-up nip frame **54** and hence the take-up nip **48**, thereby preventing the take-up nip **48** from engaging the strap **4** and take-up wheel **46**. When the rotatable frame **32** moves out of the first position, the projection **52** allows the take-up nip **48** to engage the take-up wheel **46**, thereby allowing the take-up wheel **46** to frictionally engage the strap **4** and to take up excess strap **4**.

As described above, the taking-up of excess strap **4** may be selectably accomplished by selectably turning the take-up wheel **46**. As a first alternative, feed wheel **42** and feed nip **44** may remain in engagement during take-up (FIG. **3**) and may be powered in a reverse direction and cooperate with take-up wheel **46** for purposes of excess strap **4** take-up. When the excess strap **4** is taken up, feed wheel **42** and feed nip **44** may continue to rotate and slip or stall on the strap **4**, imparting a low tension on the strap **4** as seen by the object to be strapped **24**.

As a second alternative for take-up of excess strap, the drive for the take-up wheel **46** may be designed to slip or to stall at a low tension on the strap **4** when excess strap **4** is removed. If the drive for the take-up wheel **46** is designed to stall and not to slip, allowance is made to allow strap to pass the take-up wheel **46** when the rotating frame **32** moves from the first to the second position (FIGS. **3**, **4**). The take-up wheel **46** may be designed to slip enough to allow the strap **4** to pull past. Alternatively, take-up wheel **46** may be provided with clutches to allow motion of rotatable frame **32** from the first to the second position to overcome the strap **4** tension allowed by the clutches and to pull strap past the take up wheel **46**.

As a third alternative for take-up of excess strap **4**, the motion of rotatable frame **32** from the first to the second position may begin before all excess strap **4** is taken up by the other components. The strap **4** necessary to create the longer strap **4** path created by the motion of rotatable frame **32** from the first to the second position (FIGS. **6**, **7**) then would be supplied in whole or part by the excess strap **4** of buckle **51** (FIG. **4**).

Transition to final tension: FIG. **6** shows the initiation of the rotation of the rotatable frame **32** from the first to the second position and hence the change in the path of strap **4** from the first, or feed/take-up strap path to the second, or tensioning strap path. The strap **4** is maintained in position by the engaged (but free-wheeling) feed wheel **42** and feed nip **44** and by the take-up wheel **46** and take-up nip **48**. The motion of the rotatable frame **32** elastically bends the strap **4** around the driving wheels **28**, **30**, lengthening the strap **4** path and partially wrapping the strap **4** around the strap-engaging surfaces **29**, **31** of driving wheels **28**, **30**. The strap **4** required to create the lengthened strap **4** path is pulled by the rotatable frame **32** and driving wheels **28**, **30** assembly past take-up wheel **46** and take-up nip **48**. Alternatively, a friction drive **108** (FIG. **17**) may feed adequate strap **4** to accommodate the lengthened strap **4** path. The driving wheels **28**, **30** are free-wheeling and impart no pulling force on the strap **4**.

A sprocket **56** (FIG. **12**) and chain drive **58** transfer power from rotatable frame drive motor **60** and hence control the motion of the rotatable frame **32**. Alternatively, any suitable means may be used for rotating the rotatable frame **32**.

Final Tension: FIG. **7** shows two steps. In the first step illustrated by FIG. **7**, the rotatable frame **32** is fully rotated from the first to the second position. The strap **4** is in full engagement with the strap-engaging surfaces **29**, **31** of driving wheels **28**, **30**. The driving wheels **28**, **30** have moved so that a driving wheel nip **40** presses the strap **4** against first driving wheel **28**. The driving wheels **28**, **30** and driving wheel nip **40** are free-wheeling, and impart no pulling force on the strap **4**. The feed wheel **42** and feed nip **44** are in engagement, but still are free-wheeling and impart no pulling force on the strap **4**. Take-up wheel **46** and take-up nip **48** still are in engagement and are not powered. Take-up wheel **46** and take-up nip **48** thereby exert no tension on the strap **4**.

The term "second position" as used in this application refers to the fully rotated position of the rotatable frame **32** as illustrated by FIG. **7**. The second strap path (corresponding to the second position) is longer and hence requires more strap **4** than does the first strap path (corresponding to the first position illustrated by FIG. **1**). FIG. **11** provides more detail of the tensioning assembly **16** when in the second, or tensioning, position.

In the second step illustrated by FIG. **7**, the driving wheels **28**, **30** are powered and begin to turn (relatively) slowly and with a high torque. The pressure of the driving wheel nip **40** on the first driving wheel **28** coupled with the large angular contact between the strap **4** and the strap-engaging surfaces **29**, **31** of driving wheels **28**, **30** allow the driving wheels **28**, **30** to exert a large pulling force on the strap **4** in the direction of the arrow shown in FIG. **7**, propelling strap through the tensioning apparatus **16**. The strap **4** is thereby placed under high tension by the force exerted by the rotating driving wheels **28**, **30**. The feed wheel **42** and feed nip **44** are still engaged but still are free-wheeling. The take-up wheel **46** and take-up nip **48** still are engaged and may be selectably powered to remove strap exiting the tensioning assembly **16**. At an appropriate tension, the driving wheels **28**, **30** stop or stall and the strapping cycle is completed by conventional means, including cutting and welding the strap by securing-cutting-welding assembly **26** (FIG. **1**).

To prevent the tension of the strap **4** from rotating the rotatable frame **32** as the driving wheels **28**, **30** are rotated, a cam **62** (FIGS. **14**, **15**) activates a latch **64**, causing the latch **64** to engage a corresponding opening **66** in the rotatable frame **32**, preventing rotation of the rotatable frame **32** in response to tension on the strap **4**. When tensioning of the strap **4** is complete and the loop **22** is welded or otherwise fastened, the cam **62** advances, removing the latch **64** from engagement with the opening **66**, unlocking the rotatable frame **32** and allowing the rotatable frame **32** to rotate.

As an alternative and as shown by FIG. **16**, the rotatable frame may be moved by a rotatable frame drive motor **60** operating a worm gear **70**. The worm gear **70** turns a corresponding gear **72** on the rotatable frame **32**. The worm

gear **70** alternative is self-locking, and no locking mechanism, such as the latch **64** mechanism of the foregoing alternative, is required.

The greater the angle that the rotatable frame **32** can rotate without mechanical interference, the greater the frictional engagement and the higher the possible tension that can be placed on the strap **4**. The angle through which the rotatable frame **32** rotates may be selected to allow application of the desired amount of tension to the strap **4** with the least motion of the rotatable frame **32**.

A first means for turning the driving wheels **28**, **30** appears on FIG. **12**. A driving wheel gear motor **74** is mounted directly to the rotatable frame **32** with screws **76**. The output shaft **78** of the driving wheel gear motor **74** turns a pinion gear **80** that turns a mating gear **82** on a shaft **84** of the first driving wheel **28**. Gear teeth **86** mounted on the periphery of the first driving wheel **28** mate with gear teeth **88** on the periphery of the second driving wheel **30**, thereby turning the second driving wheel **30**. Gear teeth **86**, **88** together define a channel **106** forming the strap-engaging surfaces **29**, **31** of driving wheels **28**, **30** restraining motion of strap **4**.

A second means for turning the driving wheels **28**, **30** is shown by FIG. **13**. A driving wheel gear motor **90** drives an output shaft **92**. The driving wheel gear motor **90** is mounted on a rotatable frame **32**. The driving wheel gear motor output shaft **92** turns a cylinder **94** through an overrunning clutch **96**. The cylinder **94** is supporting within the structure of the rotatable frame **32** by cylinder support bearings **98**. A pinion gear **100** mounted to the cylinder **94** turns a corresponding gear **102** on the shaft **104** of the first driving wheel **28**. The first driving wheel **28** in turn drives the second driving wheel **30** through gear teeth **86**, **88** appearing on the periphery of the driving wheels **28**, **30**. As in the first driving wheel drive means, gear teeth **86**, **88** together define a channel **106** forming the strap-engaging surfaces **29**, **31** of driving wheels **28**, **30** restraining motion of strap **4**.

The use of the overrunning clutch **96** (FIG. **13**) allows the rotation of the rotatable frame **32** from the feed/take-up position to the tensioning position while fast take-up is underway. Rotation of the rotatable frame **32** during fast take-up will cause the strap-engaging surfaces **29**, **31** of driving wheels **28**, **30** to frictionally engage the strap **4**. In the absence of the overrunning clutch **96**, frictional engagement between the driving wheels **28**, **30** and strap **4** would prevent fast take-up from occurring. Use of the overrunning clutch **96** allows the driving wheels **28**, **30** to spin freely in the direction of take-up, allowing the take-up wheel to complete the take-up of excess strap **4** even though the driving wheels **28**, **30** and strap **4** are engaged.

The conventional means for cutting the strap **4** include knives or other sharp edges or heated blades or wires. Conventional means for securing the loop **22** of strap **4** includes welding with heat or friction and the use of clamps.

Return to feed position: FIG. **8** shows the rotatable frame **32** returning to the feed/take-up position in preparation for feeding more strap **4** for another object to be strapped **24**. The rotatable frame **32** may be operably connected to the take-up wheel **46** and take-up nip **48**. As the rotatable frame **32** rotates to the first position, the rotatable frame **32** turns the take-up wheel **46** a predetermined number of rotations to take up slack in the strap **4**. Once the rotatable frame **32** returns to its first position and the slack is removed from the path of the strap **4**, the strapping machine **2** is ready to feed additional strap **4** for another object to be strapped **24** (FIG. **3**).

An embodiment of the operable connection between the rotatable frame **32** and take up wheel **46** providing for take-up of excess strap **4** at the conclusion of tensioning is shown by FIG. **17**. From FIG. **17**, a friction drive **108** is connected to take-up wheel **46** by a common shaft **110**. The friction drive **108** frictionally engages the rotatable frame **32** such that the motion of the rotatable frame **32** between the first and second positions and between the second and first positions causes the friction drive **108** to rotate the take-up wheel **46**, either feeding or taking up an appropriate amount of strap to accommodate the difference in the length of the strap **4** path between the first, or feed/take-up strap path and the second, or tensioning strap path.

The common shaft **110** (and hence the take-up wheel **46** and friction drive **108**) is connected to a take-up drive motor **114**. Take-up drive motor **114** is engergized and turns take-up wheel **46** during take-up of excess strap **4** (illustrated by FIGS. **5** and **10**). At other times during the strapping cycle, take-up drive motor **114** is not engergized and does not impart force to strap **4**.

Indentations **116** (FIGS. **14**, **15**) prevent friction drive **108** from engaging rotatable frame **32** when rotatable frame is fully rotated to either the first or second position. Take-up drive motor **114** is not energized when rotatable frame **32** is moving between the first and second positions.

FIG. **9** shows construction and operation of the driving wheel nip **40** and take-up wheel nip **48** in the feed position. Driving wheel nip **40** is supported by driving wheel nip frame **118** which swivels on driving wheel nip pin **120**. Driving wheel nip spring **122** assembly urges driving wheel nip **40** against second driving wheel **30**. In the feed position, driving wheel nip **40** does not engage strap **4** (dashed line) and driving wheels **28**, **30** impart no force to strap **4**. Take-up nip **48** is supported by take-up nip frame **54**, which swivels on take-up nip pin **124**. A spring **125** urges take-up nip **48** against take-up wheel **46**. In the feed position as shown by FIG. **9**, projection **52** prevents take-up nip frame **54** and hence take-up nip **48** from engaging strap **4** and take-up wheel **46**. Take-up wheel **46** and take-up nip **48** impart no force on strap **4** in the feed position.

FIG. **10** shows construction and operation of the driving wheel nip **40** and take-up wheel nip **48** in the take-up position. Rotatable frame **32** is rotated clockwise by approximately five degrees, causing projection **52** to release take-up nip **48** so that take-up nip **48** engages strap **4** and take-up wheel **46**. Take-up drive motor **114** (FIG. **17**) is energized, turning take-up wheel **46** and removing excess strap **4**. Detector **126** detects revolution of lobed wheel **128**, thereby detecting rotation of the take-up nip **48** and motion of strap **4**. Lobed wheel **128** stops rotating when excess strap is taken up and such stoppage is detected by detector **126**.

FIG. **11** shows the rotatable frame **32**, driving wheels **28**, **30** and driving wheel nip **40** in the second, or tensioning, position. Rotatable frame **32** has rotated so that driving wheel nip **40** presses against strap **4** and first driving wheel **28**. Driving wheel nip spring **122** determines the force applied by driving wheel nip **40** against strap **4** and first driving wheel **28**. Driving wheel **28**, **30** drive motor is energized, rotating first driving wheel **28**. Gears **86**, **88** transfer rotational energy from first driving wheel **28** to second driving wheel **30**. Gears **86**, **88** also define a channel **106** (FIG. **12**) controlling motion of strap **4**. Rotation of driving wheels **28**, **30** applies high tension to strap **4**.

FIGS. **18** through **23** illustrate the sequential operation of a second embodiment of the Invention. FIG. **18** shows the strap **4** and first alternative take-up, tensioning and feed assemblies **14**, **16**, **18** in the first, or feed/take-up strap path

during feeding of strap **4**. Feed wheel **42** and feed nip **44** are engaged, powered, and feed strap **4** in the direction indicated at a high rate of speed. Take-up wheel **46** and tensioning wheel **130** guide strap **4**, but are free-wheeling and do not impart force to strap **4**.

FIG. **19** shows the completion of feeding for the second embodiment. Mechanical or electrical detectors detect completion of loop **22** (FIG. **1**) and separate feed nip **44** from feed wheel **42**, thereby interrupting feed of strap **4**. Take-up wheel **46** and tensioning wheel **130** continue to guide strap **4**, but impart no force on strap **4**.

FIG. **20** shows the take-up of excess strap for the second embodiment. Take-up nip **48** engages take-up wheel **46** and take-up wheel **46** is powered, pulling strap **4** in the direction indicated. Feed nip **44** engages feed wheel **42** to guide strap **4**, but feed nip **44** and feed wheel **42** are not powered and rotate freely, allowing take-up of strap **4** by take-up wheel **46**.

FIG. **21** shows the transition from the first, or feed/take-up strap path to the second, or tensioning strap path. Tensioning wheel **130** is advanced in a generally rectilinear motion between feed wheel **42** and take-up wheel **46** so that the path of strap **4** is lengthened as strap **4** engages more of the strap-engaging surface **132** of tensioning wheel **130**, take-up wheel **46** and feed wheel **42**. Take-up wheel **46** or tensioning wheel **130** is powered and rotates to apply an initial tension on strap **4**.

FIG. **22** shows the tensioning wheel **130** fully engaged with strap **4** and with take-up wheel **46** and feed wheel **42**. The strap **4** now follows the second, or tensioning strap path. Tensioning wheel **130** and take-up wheel **46** are powered and turn relatively slowly and with high torque. The frictional engagement between strap **4**, the strap-engaging surface **132** of tensioning wheel **130** and take-up wheel **46** allow a high tension to be placed on strap **4**, propelling strap **4** through tensioning apparatus **16**. Strap **4** then is cut and welded by the securing-cutting-welding apparatus **26** (FIG. **1**), completing the strapping operation.

A principal difference between the first embodiment (FIGS. **1**–**17**) and the second embodiment (FIGS. **18-23**) is that the second embodiment uses generally rectilinear motion to move between the first strap path and the second strap path while the first embodiment uses rotary motion.

FIG. **23** shows the tensioning wheel **130** returning to its first position shown by FIG. **18** and returning the strap **4** to the first, or feed/take-up strap path, ready to feed more strap **4** for a new object to be strapped **24** (FIG. **1**).

A means for applying tension to a strap **4** of this Invention may comprise one or more rotating wheels (as the driving wheels **28**, **30** of the first embodiment or the tensioning wheel **130** of the second embodiment). The frictional engagement may be supplemented by a mechanical engagement; as, for example, the use of toothed or knurled wheels, belt or strap-engaging body to mechanically engage the strap.

For the purposes of this application, a strap path is a distinct course followed by the strap as it moves in either the feed or the take-up direction through the tensioning apparatus. Strap follows the strap path in either the feed direction (toward the object to be strapped) or the take-up direction (away from the object to be strapped). Strap following a strap path does not move in both the feed and take-up directions at the same time.

Many different embodiments of the above invention are possible. This application is intended to address all possible embodiments and is limited only as described in the following claims.

I claim:

1. An apparatus for applying tension to a strap in a strapping machine, the apparatus comprising:

a. a first driving wheel and a second wheel, each of said first driving wheel and said second wheel having an axis of rotation, said axes of rotation of said first driving wheel and said second wheel being substantially parallel, said axis of rotation of at least one of said first driving wheel and said second wheel having a first position and a second position with respect to said axis of rotation of the other of said first driving wheel and said second wheel;

b. said first driving wheel and said second wheel defining a selectable first strap path when said axis of rotation of said at least one of said first driving wheel and said second wheel is in said first position;

c. said first driving wheel and said second wheel defining a selectable second strap path when said axis of rotation of said at least one of said first driving wheel and said second wheel is in said second position;

d. said first driving wheel having a periphery, said periphery of said first driving wheel defining a first strap-engaging surface, said first driving wheel being adapted to rotate;

e. said first strap path being configured such that when said first strap path is selected said first strap-engaging surface does not operatively engage the strap;

f. said second strap path being configured such that when said second strap path is selected the strap is wrapped partially around said periphery of said first driving wheel, said second strap path being further configured such that when a sufficient initial tension is applied to the strap, said initial tension causes the strap to apply a sufficient force to said first strap-engaging surface to cause a frictional engagement between said first strap-engaging surface and the strap, said rotation of said first driving wheel when said first strap-engaging surface is in frictional engagement with the strap tensioning the strap;

g. said second strap path being configured so that the strap does not move in both a feed direction and a take-up direction at the same time during tensioning of the strap.

2. The apparatus of claim **1** further comprising: means for placing said initial tension upon the strap.

3. The apparatus of claim **2** further comprising: means for rotating said first driving wheel.

4. The apparatus of claim **3** further comprising: selection means for selecting said first strap path or said second strap path.

5. The apparatus of claim **4**, said means for selecting said first strap path or said second strap path comprising: a rotatable frame, at least one of said first driving wheel and said second wheel being rotatably attached to said rotatable frame, said rotatable frame having a first rotatable frame position defining said first strap path and a second rotatable frame position defining said second strap path; a means to rotate said rotatable frame from said first rotatable frame position to said second rotatable frame position and from said second rotatable frame position to said first rotatable frame position.

6. The apparatus of claim **5** wherein said first driving wheel is rotatably attached to said rotatable frame, said second wheel is a second driving wheel, said second driving wheel is rotatably attached to said rotatable frame, said second driving wheel has a periphery said periphery of said

second driving wheel defines a second strap engaging surface, said second driving wheel being adapted for rotation.

7. The apparatus of claim **6** wherein:

a. said periphery of said first driving wheel and said periphery of said second driving wheel together define a gap, said gap being sufficiently large that the strap is able to pass through said gap without engaging said first or said second strap-engaging surface when said rotatable frame is in said first position;

b. said second strap path being configured such that when said second strap path is selected the strap is wrapped partially around said second driving wheel, said second strap path being further configured such that when a sufficient initial tension is applied to the strap, said initial tension causes the strap to apply a sufficient force to said second strap-engaging surface to cause a frictional engagement between said second strap-engaging surface and the strap, said rotation of said second driving wheel in cooperation with said rotation of said first driving wheel when said first and said second strap-engaging surfaces are in said frictional engagement with the strap tensioning the strap; and

c. means for rotating said second driving wheel.

8. The apparatus of claim **7** wherein:

a. said rotatable frame has a rotatable frame axis of rotation;

b. said rotatable frame axis of rotation being located substantially between said first driving wheel axis of rotation and said second driving wheel axis of rotation.

9. The apparatus of claim **8** further comprising: means for feeding and for taking up the strap to accommodate motion of said rotatable frame from said first rotatable frame position to said second rotatable frame position and to accommodate motion of said rotatable frame from said second rotatable frame position to said first rotatable frame position.

10. The apparatus of claim **9**, said means for feeding and for taking up the strap comprising:

a. a take-up wheel operably connected to said rotatable frame; and

b. means for rotating said take-up wheel.

11. The apparatus of claim **10**, said means for rotating said take-up wheel comprising: a friction drive connected to said take-up wheel and configured to frictionally engage said rotatable frame such that movement of said rotatable frame from said second rotatable frame position to said first rotatable frame position will rotate said friction drive and said take-up wheel thereby taking up the strap to accommodate motion of said rotatable frame while movement of said rotatable frame from said first rotatable frame position to said second rotatable frame position will rotate said friction drive and said take-up wheel thereby feeding the strap to accommodate motion of said rotatable frame.

12. The apparatus of claim **7**, said means for rotating said first driving wheel and said second driving wheel comprising: a driving wheel motor attached to and rotating with said rotatable frame, said driving wheel motor being operably connected to said first and said second driving wheels.

13. The apparatus of claim **12** further comprising: an overrunning clutch, said driving wheel motor being operably connected to said first and said second driving wheels through said overrunning clutch.

14. The apparatus of claim **7**, said means for rotating said first driving wheel and said second driving wheel comprising:

a. a first driving wheel gear arrayed on said periphery of said first driving wheel; said first driving wheel gear defining a first driving wheel strap-confining channel on said first driving wheel;

b. a second driving wheel gear arrayed on said periphery of said second driving wheel, said first driving wheel gear and said second driving wheel gear each being configured so as to operably mesh one with the other, said second driving wheel gear defining a second driving wheel strap-confining channel on said second driving wheel.

15. The apparatus of claim **6**, said means for applying said initial tension to the strap comprising: a driving wheel nip engaging the strap between said first driving wheel and said driving wheel nip when said rotatable frame is in said second position, said first driving wheel being adapted to rotate to apply said initial tension to the strap.

16. The apparatus of claim **6**, said means for applying an initial tension to the strap comprising: a take-up wheel and a take-up nip, said take-up nip and said take-up wheel selectably engaging the strap and being operably connected to said rotatable frame, said take-up wheel or take-up nip rotating to apply said initial tension to the strap.

17. A strapping machine apparatus for tensioning a strap about an object, said strap having a free end, the apparatus comprising:

a. gripping means for selectably gripping the free end of the strap;

b. means for applying an initial tension to the strap against a resistance of said gripping means, said means for applying said initial tension to the strap being adapted to selectably engage the strap;

c. means for applying a final tension to the strap, said means for applying a final tension to the strap being located to selectably engage the strap intermediate between said means for gripping the free end of the strap and said means for applying said initial tension to the strap, said means for applying a final tension to the strap being configured so that no portion of the strap intermediate between said means for gripping the free end of the strap and said means for applying said initial tension to the strap moves in both a feed direction and a take up direction at the same time when said means for applying a final tension to the strap is selectably engaged with the strap and applying tension to the strap.

18. The apparatus of claim **17** said means for applying final tension to the strap comprising:

a. a first selectable strap path, said means for applying final tension to the strap having a first position and a second position, said first selectable strap path being defined by said means for applying final tension to the strap when said means for applying final tension to the strap is in said first position;

b. a second selectable strap path, said second selectable strap path being defined by said means for applying final tension to the strap when said means for applying final tension to the strap is in said second position;

c. selection means for selecting said first selectable strap path or said second selectable strap path;

d. a first driving wheel having a first strap-engaging surface, said first strap path being configured such that when said first strap path is selected by said selection means, said first strap-engaging surface does not operatively engage the strap, said second selectable strap path being configured such that when said second selectable strap path is selected the strap is wrapped partially about said first strap-engaging surface, said second strap path being further configured such that

when a sufficient initial tension is applied to the strap, said initial tension causes the strap to apply a sufficient force to said first strap-engaging surface to cause a frictional engagement between said first strap-engaging surface and the strap, said first driving wheel being adapted to rotate, said rotation of said first driving wheel and said frictional engagement between said first strap-engaging surface and the strap placing final tension on the strap.

19. The apparatus of claim **18**, said means for selecting said first strap path or said second strap path comprising:

a. a rotatable frame said first driving wheel being rotatably attached to said rotatable frame;

b. a second driving wheel, said second driving wheel being rotatably attached to said rotatable frame, said second driving wheel defining a second strap-engaging surface, said first strap path being configured such that when said first strap path is selected by said selection means, said second strap-engaging surface does not operatively engage the strap, said second selectable strap path being configured such that when said second selectable strap path is selected the strap is wrapped partially about said second strap-engaging surface, said second selectable strap path being further configured such that when said second strap path is selected and when a sufficient initial tension is applied to the strap, said initial tension causes the strap to apply a sufficient force to said second strap-engaging surface to cause a frictional engagement between said second strap-engaging surface and the strap, said second driving wheel being adapted to rotate, whereby said rotation of said first and said second driving wheels and said frictional engagement between said first and said second strap-engaging surfaces and the strap places final tension on the strap.

20. The apparatus of claim **19** wherein said rotatable frame has a first rotatable frame position defining said first strap path and a second rotatable frame position defining said second strap path, the apparatus further comprising: means to rotate said rotatable frame between said first rotatable frame position and said second rotatable frame position and between said second rotatable frame position and said rotatable frame first position.

21. The apparatus of claim **20** wherein said first driving wheel has a first driving wheel periphery, said first driving wheel periphery defining said first strap-engaging surface, said second driving wheel has a second driving wheel periphery, said second driving wheel periphery defining said second strap-engaging surface, said peripheries of said first and said second driving wheels together define a gap, said gap having sufficient dimensions to allow the strap to pass through the gap without engaging said first or said second strap engaging surfaces when said rotatable frame is in said first position.

22. A method for applying tension to a strap around an object comprising the steps of:

a. selecting a first strap path;

b. feeding the strap around the object through the first strap path to form a loop;

c. securing an end of the strap;

d. taking up excess strap;

e. selecting a second strap path, said second strap path being configured such that the strap is wrapped partially around a first driving wheel, said second strap path being further configured such that when a sufficient initial tension is applied to the strap, said initial tension causes the strap to apply a sufficient force to said first driving wheel to provide frictional engagement between the strap and said first driving wheel;

f. applying said sufficient initial tension to the strap;

g. rotating said first driving wheel to apply a final tension to the strap by the frictional engagement of said first driving wheel and the strap in said second strap path, said fianl tension to the strap in said second strap path being further configured so that the strap does not move in both a feed direction and a take-up direction at the same time during tensioning of the strap.

23. The method of claim **22** comprising the further sequential steps of: cutting and welding said strap, thereby preparing the strapping machine to strap a new object.

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